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SOME BASIC CONCEPTS

OF

FAST BREEDER REACTOR SAFEGUARDS

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1.1 Introduction

The IAEA's experience in applying safeguards for fast breeder fuel cycle facilities is very limited both in time and scope. Of the fast breeder reactor fuel cycle under development, the liquid-metal fast breeder reactor (LMFBR) cycle has reached the most advanced stage. There are, as yet, no fully commercial fast breeder reactors in operation under Agency safeguards. Those LMFBR fuel cycle facilities currently under Agency safeguards include a few demonstration fast breeder reactors and a few small mixed oxide fuel fabrication plants.

The quantities of plutonium and fissile uranium, the fuel handling systems, and the storage methods for the fuel assemblies of fast breeders will have a significant impact on Agency safeguards methods and techniques. The plutonium and fissile uranium throughput, the high fissile content, and the use of sodium coolant for the LMFBR may require development of additional safeguards techniques beyond those for the thermal light-water (LWR) fuel cycle. Although there are some similarities in principle between thermal reactors and FBRs which might lead to similar safeguards approaches for the two systems, there are some differences which appear to be fundamental from a safeguards point of view.

Because of the possible safeguards issues which may arise as a consequence of the "inaccesssibility" of fuel assemblies before, during and after irradiation it may be important from a safeguards point of view to consider also the safeguarding activities at the fuel fabrication plant, the shipping of fresh assemblies to the reactor and receipt of the irradiated fuel assemblies at the reprocessing plant or at storage. However, because of the range of topics which need to be considered when developing even a conceptual approach, it is proposed to restrict the range of discussion topics in this report to a few key areas of safeguards importance at FBR only.

The differences between thermal and fast reactors that may have safeguards significance will include in the case of the FBR:

i) there are two basic types of fresh assemblies containing nuclear material, fuel assemblies and blanket assemblies;

ii) the amount of direct-use material in unirradiated form per fuel may be only slightly less or may even exceed one significant quantity so that fresh fuel assemblies have high safeguards significance;

iii) irradiated fuel assemblies will have approximately the same quantity of special fissionable material per item as fresh assemblies and irradiated blanket assemblies have probably comparable or higher amounts per item than thermal fuel assemblies. Both types are of high safeguards significance;

iv) fresh fuel and irradiated fuel and blanket assemblies are stored under sodium and remain so for several years, therefore they are difficult-to-access for verification.

1.2 FBR Design Principles

1.2.1 Design Features

There are currently two basic design philosophies for FBRs; the 'pool' type where the core and primary sodium coolant circuits are immersed in the sodium coolant within the reactor vessel; the 'loop' type where only the core is immersed in sodium in the reactor vessel and the primary coolant circuit extends beyond the reactor vessel with the primary pumps and intermediate heat exchangers located externally. The alternative design principles appear to have led to two different fuel handling procedures which may require slightly different safeguards approaches for the two types of design. Before considering in some detail the basic fuel handling routes through an FBR it is worth considering the design differences between these two types as they affect the fuel handling routes and procedures.

From a safeguards point of view the distinction might be considered between 'integrated' topology of fuel locations (as in the pool design) 'segmented' locations (as in the loop design) in respect of fuel handling routes. It is not obvious that an integrated topology and dedicated fuel handling route is a fundamental requirement for a pool type reactor; nor that a separate fuel locations is a fundamental requirement for a loop design. The safeguards significant differences between these two design philosophies are considered in more detail below. It is concluded from the analysis that there are no fundamental differences which have safeguards significance; detailed design and operational procedures at individual facilities are likely to be more significant.

The pool type philosophy is exemplified by the French Superphenix I design (see Figure 1) where the reactor refuelling route is an integral part of the structure. In order to load fuel into the reactor, fresh fuel is introduced into the fuel storage carousel. From there it is transferred into the reactor vessel through fixed transfer ramps and through the rotating transfer lock located at the head of the transfer ramps. Irradiated fuel is transferred in the reverse direction through the same route. The locations for fuel assemblies within the reactor core and breeder lattice and in the storage carousel are accessed by separate dedicated fuel handling machines located in the roof structures of the reactor and storage vessel. The transfer of fresh fuel into the storage carousel and the shipment of irradiated fuel out of it require mobile handling machines which could be either trolley mounted or moved by overhead cranes. The UK Prototype Fast Reactor (PFR) is based on similar fuel handling principles. The UK design for a large Commercial Demonstration Fast Reactor (CDFR) is also based on similar fuel handling principles. The fuel storage carousel acts as an in-sodium buffer store for fresh fuel prior to reactor loading and for spent fuel decay-heat removal prior to shipment. There will probably be an intermediate fresh fuel store between the receipt bay of the facility and the in-sodium buffer store and an intermediate irradiated fuel store between the in-sodium buffer store and the shipment bay. These intermediate stores will be common features for both pool and loop type designs.

The loop type philosophy is exemplified by the FRG Kalkar SNR-300 (Fig. 2) prototype FBR. In this design the fuel handling route between the in-sodium store and the reactor vessel is not a fixed part of the structure. Fuel transfers between nearly all locations are made by mobile handling machines and not be dedicated machines having restricted movements. The exception being transfers within the reactor vessel between the transfer position and the core/breeder lattice. The mobile handling machines may be trolley mounted or moved by overhead cranes. Loop type reactors will probably have a similar number of buffer storage and fuel handling locations as a pool type design.

1.2.2 Fuel Handling

In order to consider a conceptual safeguards approach some basic facility design has to be defined. The fuel handling route through an FBR as shown in Figure 3 will be used for this purpose. The defined route is considered to be equally appropriate for both integrated and segmented fuel route designs but, there will be differences in the operational procedures at individual facilities which may lead to different safeguards requirements at specific locations. At this stage only the general handling principles relevant to both design philosophies are considered. The following steps refer to the activities at the numbered locations in Figure 3:

- fresh fuel and blanket assemblies are received at the Fresh Fuel Receipt Bay (i), in the transport containers in which they were placed at the fabrication plant;

- fuel assemblies and other reactor components can be identified and tested for dimensional quality and coolant flow performance at the Quality Assurance Laboratory (ii). This may be done prior to transfer to the Intermediate Fresh Fuel Store (iii) or at some later time;

- fuel and blanket received may be stored in air in the Intermediate Fresh Fuel Store until such time as they are due to be transferred to the In-Sodium Store (v). They may be stored in some form of containers. The Intermediate Store may function as a buffer store in order to maintain an adequate flow of items;

- assemblies will be removed from their storage positions of the Fresh Fuel Store, identified and transferred to the In-Sodium Store (v);

- items will be placed in the In-Sodium Store for a period of acclimatisation before transfer to the reactor, (vi);

- fuel assemblies may reside in the reactor core from two to four years (particularly for large power reactors) and blanket assemblies for up to ten years. Upon discharge from reactor core irradiated assemblies are transferred to the Intermediate In-Sodium Irradiated Fuel Store (ix) which in some designs is combined with (v). The period for decay-heat cooling the in-sodium store may range from one to two years.

- in some designs, after cooling in the In-Sodium Store, the irradiated fuel assemblies are transferred to the Gas-cooled store or water pools (x).

- decontamination of fuel assemblies refers to the removal of sodium from the irradiated items. Decontaminated items may be transferred directly to the Irradiated Fuel Store (x) either in inert gas atmosphere or in water pools or to the post-irradiation examination (PIE) Laboratory (viii) for post-irradiation inspection;

- post-irradiation inspection may amount to no more than a visual check of identity, if possible, and integrity of the item. On the other hand post-irradiation examination facilities may be installed with the capability to dismantle a fuel assembly, withdraw fuel pins and remove sections of pin.

- the Irradiated Fuel Store (x) can function as a short-term buffer store to ease the flow of items to the Shipping Bay. It may also serve as a short/medium term store to extend the decay-heat cooling period before shipments. Items will probably be stored in transit canisters.

- at the Shipping Bay, irradiated items will be loaded into heavily shielded shipping casks for onward transfer either to a further storage location or to a reprocessing plant.

It is not possible to put precise values on the residence time of fuel assemblies at each location throughout the reactor fuel route but some illustrative times might be helpful. Clearly the timing will depend to some extent upon the design of the facility but primarily they will be determined by the operating philosophy. The following times are suggested as being typical:

Fresh Fuel Store	~	months
Sodium-Store	~	months (fresh assemblies)
		1-2 years (irradiated assemblies)
Reactor Core	~	2-4 years (fuel assemblies)
		5-10 years (blanket assemblies)
Gas-cooled Store	~	months
Water Pool (if any)	~	years

Refuelling is generally carried out 'off-load' at about 6-8 months intervals. Typically one-third of the core and one-eighth of the blanket assemblies will be replaced at each campaign. Refuelling operations could be expected to take about two weeks per campaign, during which time selected irradiated assemblies are transferred from their Reactor locations into the In-Sodium Store and fresh assemblies are transferred in the opposite direction. At this time some of the retained fuel assemblies may be shuffled between locations within the Reactor. Because of the need for controlled environments throughout the transfer routes and in the storage vessels and reactor, there are a limited number of locations through which fuel assemblies can be transferred from one area to another. These 'access ports' are normally closed except during the period when items are in the process of being transferred. The process of transfer will probably require the fuel handling device to interlock with the access port in order to prevent a breach of the controlled environment. In order to minimise the number of access ports, the same fuel routes will be used for fuel assemblies, blanket assemblies and other assemblies. The total number of ports will depend particularly upon the design philosophy, the segmented fuel route probably requiring more than the integrated fuel route.

1.2.3 Fuel Assembly Design

Figure 4 shows a typical fuel assembly. Present reactor designs all appear to rely on a hexagonal form for the core and breeder assemblies and for the non-fissile replaceable components of the core. Whilst the detailed design of each type of item may differ, in order to prevent mislocation when loading into the reactor, the types may not be readily distinguishable visually. The driver fuel assemblies will probably contain either enriched UO_2 or Pu/U mixed oxide (MOX) with some depleted uranium in an axial breeder section. The fuel is contained within fuel pins retained by lattice structures within the wrappers. There may well be more than one type of driver fuel assembly with different proportions of Pu:U in the MOX for different zones within the core. This material will have been under safguards at the fabrication plant and shipments to the reactor should be duly reported in accordance with the Safeguards Agreement. Because the breeder fuel assemblies contain only depleted uranium, also in pins, they may be fabricated at a separate facility from the driver fuel.

The typical ranges of nuclear materials that may be contained in FBR fuel assemblies are as follows:

	Fresh Fuel	Irradiated Fuel
Core Assembly. Plutonium (kg)	5-25	4,5-24
wt% enrichment Pu/Pu+U	15-40	15-40
Breeder Assembly. Depleted U(kg)	50-100	48-210
Plutonium (kg)	zero	1,5-8

1.3 Relevant Safeguards Objectives and Criteria

The objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection. (INFCIRC 153, para 28). Within this definition of the objectives of IAEA safeguards there are two criteria which require further definition since they are crucial in determining the inspection requirements to meet the objectives. "A significant quantity" is taken to be the approximate quantity of nuclear material in respect of which, taking into account any conversion process involved, the possibility of manufacturing a nuclear explosive device cannot be excluded. The significant quantities adopted by the Agency as guidelines for setting inspection goals and procedures for FBRs are as follows:

Plutonium (total element)	8 kg
Uranium (enriched > 20%)	25 kg ^{235}U content
Uranium (enriched < 20%)	75 kg ^{235}U content
Uranium (depleted)	75 kg ^{235}U content or 20t

The last two figures are appropriate to the breeder fuel elements which contain depleted uranium and to the uranium which may be introduced into the core fuel assemblies as axial breeder and may also be mixed in the (driver) core section with the plutonium. The first two categories refer to the driver fuel.

Referring to these values it can be seen that the significant quantities are equivalent to:

1-2 fuel assemblies (fresh or irradiated)
1-5 irradiated blanket assemblies
100-400 fresh blanket assemblies

"Timely detection" is incorporated into the inspection goals and procedures by adapting the detection time guidelines to the specific process and operating conditions at the facility and by taking into account available detection capabilities (technology and resources). The detection time guidelines are based on estimates of the time required to convert different forms of nuclear material to the metallic components of a nuclear explosive device. The Agency currently adopts inspection timeliness goals as follows:

Unirradiated Pu and HEU	1 month
Irradiated Pu and HEU	3 months
Uranium (< 20% U_{235})	1 year

"The risk" of early detection is expressed for the purposes of plannng inspection procedures as the probability of detecting the diversion of a significant quantity of nuclear material. The levels currently used as guidelines are a detection probability of 90-95% and a false alarm probability of $\leq$ 5%. The former criterion can be seen as setting a probability of 10-5% of failing to conclude that a diversion has taken place when in fact a diversion has occurred. The latter criterion is a 5% probability of falsely concluding that a diversion has occurred when in fact none has occurred.

2. Fundamental Issues for Safeguarding FBR

The primary objective of safeguards is to detect the diversion of significant quantities of nuclear material. Therefore materials accountancy has been adopted as the fundamental safeguards measure. Containment and surveillance are used as complementary measures to provide continuity of an accountancy knowledge.

The function of materials accountancy is to establish the flow and inventory of nuclear materials so that all materials under safeguards can be accounted for. The emphasis on independent verification is fundamental to the effectiveness of a safeguards regime. For completeness, Agency safeguards procedures must not only be capable of independent verification of declared information but also of undeclared movements of nuclear materials detection.

The credibility of safeguards measures at FBRs depends upon the ability to perform effective accountancy and to cover a wide range of potential diversion paths and concealment methods using C/S measures.

Several problem areas are identified below which give rise to issues of fundamental importance to the policy of safeguarding fast breeder reactors, including the relative importance of accountancy and containment and surveillance measures. These areas are:

1. Material accountancy applied to fresh and irradiated assemblies in connection with the problem of accessibility to nuclear material;

2. Safeguards significance of flow verification of nuclear material within the Material Balance Area at FBR;

3. Verification of receipt and shipment of nuclear material;

4. Safeguards importance of C/S measures at FBR.

2.1 Material Accountancy at FBR

In the case of a fast breeder reactor the capability of an application of accountancy measures is of particular importance because of its specific design features. The fuel handlng area at FBR is subdivided into two sub-areas, namely "accessible" and "inaccessible areas". An "accessible" area comprises the Quality Assurance Laboratory (ii) and Fresh Fuel Store (iii). In principle there are no problems in verification of the inventory of an "accessible" area where only unirradiated assemblies are present. Fresh fuel and blanket assemblies are readily accessible for independent verification by item counting and identification, and NDA measurements. Material accountancy of an accessible area is based on item counting of two types of assemblies, namely, fresh fuel and fresh blanket assemblies. On the other hand, a unique feature of the LMFBR is that both the fresh and the irradiated fuel assemblies are submerged in sodium or inert gas atmosphere in a number of locations at the reactor for a long period of time and are not readily accessible for verification. In principle all fuel assemblies are physically accessible from an operator's point of view but may not be convenient from an operational point of view or desirable from a safety point of view.

From a safeguards inspector's view point, items in locations of sodium or inert gas atmosphere may be considered difficult-to-access. These locations constitute the "inaccessible" area which contains fuel and blanket assemblies in both irradiated and unirradiated forms. Assemblies in this area cannot be visually checked or identified directly by inspectors. Remote contact identification or non-contact interrogation may no be satisfactory because of extreme environmental conditions. On the other hand it is unreasonable to expect an operator to accede to any request to remove assemblies from either location for non-routine purposes resulting in undue intrusion into routine reactor operations. In addition, transportation of assemblies from the "inaccessible" area to locations where they can at least be identified is an extremely time consuming operation. From the above-mentioned it is clear that verification of the "inaccessible inventory" presents a very difficult task indeed.

In reality the verification of inventory within the "inaccessible" area may be performed on the basis of verification of flow of nuclear material to and from this area and subsequent maintenance of this knowledge by application of C/S measures. Thus the "inaccessible inventory" may be estimated by the difference of flow of items in both directions:

INVENTORY = INPUT - OUTPUT

Verification of items flow implies the assembly's counting and their identification (categorization) by γ and n- measurements.

Under normal routine operations all fuel assemblies entering the "inaccessible" area are in unirradiated form and those leaving the area are in irradiated form. There are four types of assemblies within or in the "inaccessible area": fresh fuel and blanket assemblies and irradiated fuel and blanket assemblies. Material accountancy of the inaccessible area can only be based on the item accountancy of all four types of fuel assemblies. For accountancy purposes fuel assemblies in the reactor core would be considered fresh unless they have been discharged.

2.2 The Significance of Safeguards Verification of Flow of Nuclear Material within MBA at FBR

As has already been emphasized above, the verification of flow assemblies plays a key role for the definition of the inventory of nuclear material at the "inaccessible" area and the continuity of knowledge of nuclear material in MBA at FBR. This monitoring may be carried out either by the inspector or by the use of instrumentation. It is clear that the level of verificaton of the flow of nuclear material which can be achieved within the MBA depends upon operational procedures and design features of particular facilities and performance capabilities of the monitoring systems.

In the case of reactors with an "integrated" structure in the "inaccessible" area, there is only one access port from an accessible to the "inaccessible" area. It is normally used for transportaton of fuel assemblies between two areas only on campaign basis. It implies that an inspector can directly verify the flow of assemblies through the access port and then seal it. In the case of a "segmented" structure of the "inaccessible" area the situation is more complex because of a possible continuous regime of transfers of assemblies between a number of different locations within MBA. It may require continuous inspector's presence at the reactor for flow verification. The use of advanced (sophisticated), instrumentation for automatic verification of fuel flow and recording the information provides essential benefits and may replace the continuous inspectors presence at the facility.

In discussing the necessary level of knowledge on safeguards information on flow between (and within) different areas of the reactor, it is worth considering the safeguards significance for different types of assemblies transported within the MBA. Bearing in mind that only unirradiated (fuel and blanket) assemblies are transferred from the accessible to the "inaccessible" area and that fresh blanket assemblies have a low strategic value, it is safeguards significant to identify and count only fresh fuel assemblies entering the "inaccessible" area. However, in the case of direct verification of input to the "inaccessible" area by an inspector, in addition the flow of fresh blanket assemblies may be verified as well. On the other hand, while verifying the output of assemblies from an "inacessible" area, it is necessary to identify and count fresh fuel, irradiated fuel and irradiated blanket assemblies. These are fundamental requirements for technical features of instrumentation designed for monitoring assembly flow at fast breeder reactors.

2.3 Inventory Change Verification (Receipt and Shipment)

Inventory change verification at FBR includes verification of receipts and shipments:

APPENDIX

a) <u>Verification of Receipts</u>

In principle, there might be different alternatives for verification of receipt of fresh fuel at the reactor. Major factors which may affect the scheme of verification are as follows:

- frequency of receipts of fresh fuel;
- operational and fuel handling regime at the reactor;
- level of verificaton of fresh fuel shipped from a fuel fabrication plant.

It appears that the method of verification of receipt has to be facility specific. However, regardless of the verification scheme selected for each specific case, fresh fuel and blanket assemblies that arrive at the reactor should be verified by an inspector before they are transferred to an "inaccessible" area. Due to the high strategic value of fresh fuel, short timeliness period and possible quick transfers of fresh fuel assemblies to the "inaccessible" area, it appears that an inspector's presence on site is required each time when fuel arrives at the reactor. Verification of receipt includes a verification of integrity of transport containers and seals, counting of fuel assemblies and their measurements, if it is necessary depending on the level of verification at the fuel fabrication plant. The inspecton activities related to verificaton of receipt is described below in detail in relevant sections of this report.

Verification of a shipment has particular importance in the case of a fast breeder reactor because of the problems mentioned above related to verification and the re-establishment of inaccessible inventory at the reactor. Meanwhile, the verification of shipment presents much more difficulty at fast breeder reactors due to the same problem of accessibility to the irradiated fuel assemblies during a shipping campaign. Most of the existing designs of fast breeder reactors do not have special facilities and installed equipment for measurements of irradiated fuel. Even visual observation of the loading of assemblies in transport casks may present major difficulties. The verification of the nuclear material content of irradiated fuel has an additional significance when fuel is shipped to the long-term storage where later it is "inaccessible" for verification (e.g., dry storage). In the case of irradiated fuel being shipped to the reprocessing plant its content can be established there on receipt.

Technical feasibility of different verification methods during shipment depends on specific design features of a reactor and should be studied separately at each facility. More favourable conditions for verification of shipment are provided at FBR where water storage pools are foreseen for the cooling of irradiated fuel.

2.4 Role of C/S Measures

In safeguarding nuclear facilities, containment and surveillance are normally used as complementary techniques to provide a continuity of accountancy knowledge. In the case of fast breeder reactors it may be considered that containment and surveillance (C/S) have to fulfil a major role in areas where the items in the inventory are inaccessible to safeguards inspectors.

Safeguards approaches for Fast Breeder Reactors should rely to a great extent on C/S techniques, probably more so than on any other facility type apart from long-term storage. Analysis of the effectiveness of a safeguards approach must reflect the important contribution of C/S to that approach. Because of the level of reliance upon C/S techniques, the consequences of a loss of surveillance should be emphasised. This applies particulary to the surveillance of the access port to the inaccessible inventory. Since those items known to be in this inventory cannot be verified without an extended shut-down of the reactor and an undesirable increase in fuel handling and thereby an avoidable radiation exposure to operators and inspectors, it is essential that surveillance failure be reduced to a minimum.

C/S measures must be capable of meeting the requirements for indicating non-declared movements of fresh or irradiated assemblies. Fresh fuel assemblies can be removed from the reactor either in the form of separate items or in routinely used transport containers or other undeclared containers. In contrast, irradiated assemblies may be removed only in heavily shielded containers. Assurance of diversion detectability provided by C/S measures depends on specific design features of the reactor, the regime of fuel handling and the technical performance of C/S instrumentation. Application of advanced devices like electronic sealing systems on transport flasks and the use of installed radiation monitors for flow verification would be of benefit in solving these problems. A high level of reliability will be required to ensure that there is no loss of continuity of safeguards information in the surveillance regime.

Physical independence of C/S implementation should be considered from the point of view of maximum protection of continuity of a knowledge of nuclear material in case of a failure or circumvention of one device. This implies that a C/S system must include devices based on different physical principles which cannot fail or be circumvented by the same means.

3. An Outline Safeguards Approach

The fundamental concept of IAEA safeguards is to verify that nuclear material subject to safeguards under Agreement, is not diverted from peaceful nuclear activities. IAEA verification includes the examination of an operator's records and reports regarding the amount present, the use of nuclear material as well as independent measurements and observations conducted by the Agency. Safeguards approach for FBR (as for other facilities of the nuclear fuel cycle) is the system of nuclear material accountancy, containment and surveillance measures, and other measures chosen for implementation of safeguards. The model safeguards approach for an FBR specifies inspection goals and procedures for a reference facility, taking into consideration the relevant diversion assumptions, safeguards measures including capability of these measures, facility design information and facility practice.

The first and necessary step for the design of the specific facility safeguards approach is a complete study of all possible diversion paths which has to take account of the following factors:

- material description
- location of the material
- physical removal route
- diversion rate
- concealment methods

A set of credible diversion paths forms an assumption of diversion which is part of a credible diversion strategy and should be taken into account when designing and evaluating a safeguards approach for a particular design of an FBR.

The intended goal of diversion at an FBR would be the removal of one or several fuel assemblies (fresh or irradiated), with or without concealment actions by the diverter. Combinations of falsification of records and reports, substitution of nuclear material, interference with containment and surveillance measures may be used for concealing a diversion. To this end an Agency safeguards approach should be based on

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an appropriate redundant and support measures and procedures to facilitate the detection of any diversion attempt.

A Fast Breeder Reactor is considered a single Material Balance Area (MBA). Strategic points are selected at the FBR for the implementation of safeguards measures and include locations where key measurements related to material balance accountancy are made and where containment and surveillance measures are applied. The following flow key measurement points (KMPs) are defined at an FBR:

KMP-1	receipt of fresh fuel
KMP-2	transfer of fresh fuel from accessible to the "inaccessible" area.
KMP-3	shipment of irradiated fuel.

Additional flow KMPs may be introduced for verification of flow between different locations at an "inaccessible" area.

In the case of an FBR with a "segmented" inaccessible area, the principal inventory of KMPs at an FBR are selected as they are shown below:

KMP-A	Fresh Fuel Store
KMP-B	Sodium Cooled Store
KMP-C	Reactor Vessel
KMP-D	Gas Cooled Store
KMP-E	Irradiated Fuel Observation Cell
KMP-F	Washing Cell
KMP-G	Water Pool Store (if any).

There might be additional inventory KMPs depending on the specific design features of a particular FBR. In the case of the "integral" inaccessible area at an FBR this area may be defined as one inventory KMP.

An FBR is an item facility in which nuclear material is contained in four types of fuel assemblies:

store tc ease the flow of items to the Shipping Bay. It may also

- fresh fuel
- fresh blanket
- irradiated fuel
- irradiated blanket.

Accountancy system at an FBR is based on accounting procedures for these types of fuel assemblies which include item counting and identification, and non-destructive measurements.

Containment and surveillance measures are applied at an FBR to facilitate the procedures for inventory and flow verification. The locations for application of C/S measures are selected taking into account specific design features of the facility.

At an FBR seals may be applied in the following places and to the following items:

- Transport airlock to the reactor hall (gates and passages through which fresh fuel assemblies can be removed);
- Fresh Fuel Store;
- Access port to the inaccessible area (integrated "inaccessible" area);
- Irradiated Fuel Store(s);
- Transport containers for fresh and irradiated fuel;
- IAEA instruments and equipment.

Surveillance measures may be necessary for the following functions:

- surveillance of access points through which nuclear material could pass, such as doors, portals and other penetrations of the reactor hall.
- surveillance of fuel assembly transfer areas, fuel assembly handling mechanisms, and cask handling mechanisms.
- surveillance of fresh and irradiated fuel storage areas.
- surveillance of movements of fuel assemblies for flow verification by use of γ and n- monitors.

period when items are in the process of being transferred. The process

Design features and an operational regime at a particular reactor will essentially influence the safeguards inspections scheme. In the development of a safeguards approach and its practical implementation, the verification procedures at an FBR fuel cycle related facilities (fuel fabrication plant, reprocessing plant, interim long-term storage) will effect the scheme of an inventory change verification at an FBR.

<u>Verification of Receipt</u>

<u>First Alternative</u>

The content of fresh fuel shipped to an FBR was verified by an inspector at a fuel fabrication plant in accordance with a required level of verification including NDA measurements. Then transport containers are sealed and shipped to the FBR. On receipt of fresh fuel at the FBR, the integrity of transport containers and seals are checked and fresh fuel assemblies are counted prior to their placement in a Fresh Fuel Store.

<u>Second Alternative</u>

Fresh fuel assemblies placed in shipping containers at a fuel frabrication plant are counted and sealed by an inspector. On receipt, the content of the nuclear material is verified at a reactor by accountancy measures with required detection probability by NDA measurements.

It is likely that the first alternative has some advantages from the point of optimisation of inspection efforts.

<u>Verification of Shipment</u>

There might also be two alternatives of verification of a shipment of irradiated fuel depending on the possibility of establishing the content of nuclear materials shipped from an FBR. If the content of nuclear material can be established at a reactor, the procedure of verification is similar to the first option described above for verification of receipt of fresh fuel. It is understandable that this

Plutonium (kg)	zero	1,5-8

alternative is to be applied when irradiated fuel is shipped to the facility where its content cannot be verified (as in the case of a long-term dry storage). When irradiated fuel is shipped to a reprocessing plant, then either the first or second alternative proposed for verification of receipt of fresh fuel may be applied. It is likely that in this case, the second approach has benefits because of the more favourable possibilities of a verification of content of irradiated fuel at the reprocessing plant.

Verification of Inventory

Verification of the "Accessible" Inventory

Verification of inventory of nuclear material in the accessible area is carried out directly by counting, identification and measurements of fuel assemblies and supported by C/S measures.

Verification of the "Inaccessible" Inventory

No direct verification of the "inaccessible" area being possible, indirect verification is achieved by verification of input and output flow of assemblies to and from the "inaccessible" area. This verification is carried out either directly by an inspector or by instrumentation developed for a particular facility depending on the design features and operational regime at the reactor.

The frequency of inspection and level of verification is determined for different categories of nuclear material in line with the timeliness criteria.

4. Model Inspection Activities

4.1 General Description

As defined in the IAEA Safeguards Glossary: "Inspection goals and procedures - performance targets specified for a given facility, as required to implement the facility safeguards approach, the actual implementation and the extent to which inspections goals embodied in inspection procedures can be achieved, depend on cooperation from the State and the operator, and on the availability of manpower, safeguards equipment, inspection support services, and the IAEA budget".

At present the so called long-term criteria for inspection goal attainment are under discussion at the Agency. They are designed as criteria for effective safeguards which could reasonably be achieved within a period of 10-15 years. In the meantime, conclusions on inspection goal attainment will be based on short-term criteria which will be under development and progressively upgraded.

Taking this into account only the principal inspection activities are described in this section.

In general IAEA inspection activities at FBR should include the following procedures:

- verification of design information;
- application and servicing of containment and surveillance devices;
- monitoring of fuel flows;
- interim inventory and flow verification;
- physical inventory verification;
- verification of all nuclear material accounting data;
- inspections following unresolved anomalies.

There are three types of inspections performed for safeguarding FBR:

- Initial Physical Inventory Verification (IPIV);
- Interim Inventory and Flow Verification (IIFV);
- Physical Inventory Verification (PIV).

The aim of IPIV is to establish the initial inventory of nuclear material particularly within the "inaccessible" area before starting reactor operations. The aim of interim inspections is to carry out verification to meet timeliness criteria.

The frequency of interim inspections and level of verification is defined by the presence of three categories of nuclear material at FBR:

- unirradiated direct-use (fresh fuel assemblies);
- irradiated direct-use (irradiated fresh and blanket assemblies);
- indirect use (fresh blanket assemblies).

To meet timeliness criteria the interim inventory verification is carried out once a month for fresh fuel assemblies, once every three months for irradiated fuel and blanket assemblies, and once a year for fresh blanket assemblies.

In line with the above proposed Outline Safeguards Approach, interim inspections are also scheduled for verification of receipts and shipments. These may be combined with interim inventory verification to optimize inspection efforts.

The frequency of PIV depends on the category of nuclear material. Currently two PIVs are required for unirradiated direct-use material (fresh fuel assemblies) and one PIV is necessary for irradiated direct-use material as well as for indirect-use material (fresh blanket assemblies).

4.2 List of Principal Inspection Activities

Inventory Change Verification

Receipt

(a) The content of fresh fuel was verified and sealed at the fuel fabrication plant prior to shipment,

- verification of the integrity of a transport container and checking of the seal;
- item counting and identification of fuel assemblies received;
- witnessing the placement of fuel assemblies in Fresh Fuel Store(s);
- sealing of fresh fuel assemblies in Fresh Fuel Store(s) where this is possible;
- application of surveillance to fresh fuel;
- verification of operators' records.

(b) Content of fresh fuel was not verified at the fuel fabrication plant,

- the same activities as in (a) plus NDA measurements by sampling plan prior to sealing of assemblies in the Fresh Fuel Store(s).

Shipment

(c) Irradiated fuel is shipped to the reprocessing plant or to the storage facility where it can be verified;
- item counting and identification of irradiated assemblies (where feasible) during loading of shipping containers;*
- sealing of transport containers;
- verification of operator's records.

(d) Irradiated fuel is shipped to the storage where it is "inaccessible" for verification,

- the same activities as in (c) plus NDA measurements by sampling plan for verification of content of nuclear material shipped from reactor.

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* Verification of the content of shipped irradiated fuel using NDA measurements may be carried out at FBR if it is technically possible.

Interim Inventory Verification

(a) Fresh Fuel (once a month)

Accessible Area

- verification of seals applied in the Fresh Fuel Store(s) and to passages from the reactor hall;
- review of surveillance camera films;
- item counting and identification of fresh fuel assemblies;
- NDA measurements by sampling plan if required by criteria for inspection goal attainment;
- verification of flow of fresh fuel assemblies from accessible to the inaccessible area directly or by monitors (γ, n);
- sealing or verification of seals at the access port from accessible to the "inaccessible" area, if appropriate;
- verification of operator's records and comparison with reports.

"Inaccessible" Area

- verification of seals applied to locations at the "inaccessible" area, if appropriate;
- review of surveillance camera films;
- identification of serial numbers of assemblies by sampling plan, where feasible;
- check records of monitoring system on the flow of fresh fuel assemblies in and out of the "inacessible" area to define its inventory, if appropriate;
- compare monitoring records with operator records.

(b) Irradiated Fuel (every three months)
(Irradiated Fuel and Blanket Assemblies)

- verifiy seals applied to the "inaccessible" area;
- check surveillance of cameras films;
- identify serial numbers of assemblies by sampling plan;

- check records of monitoring system on flow of irradiated assemblies to define the "inaccessible" inventory of irradiated fuel, if appropriate;
- compare monitoring records with operator records;
- item count, identification and NDA measurements of the irradiated assemblies in water pool, if any;
- compare Inventory Change Reports and Operator Accounting Records.

Physical Inventory Verification (PIV)

Fresh Fuel (twice a year)

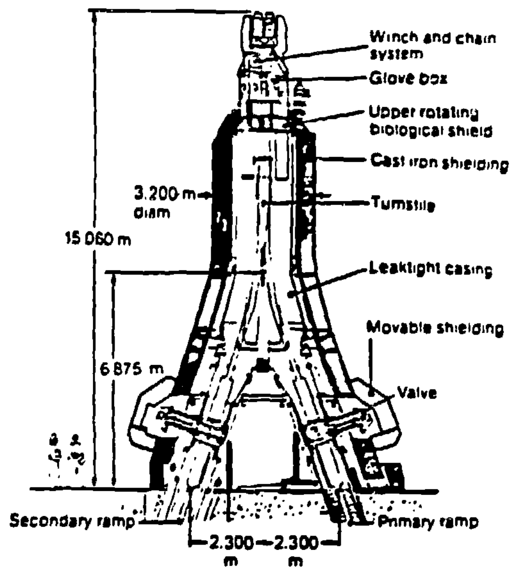
- the same list of activities as for Interim Inspections but with a higher detection probability for identification and NDA measurements of fuel assemblies (where feasible) to meet relevant criteria;
- verification of Material Balance Closing.

Irradiated Fuel (once a year)

- the same inspection activities as for Interim Inspections but with higher detection probability for identification and NDA measurements of fuel assemblies (where feasible) to meet relevant criteria;
- verification of Material Balance Closing.

Indirect-Use Material (fresh blanket assemblies) - once a year

- verification of seals applied to assemblies once a year;
- item counting and identification;
- NDA measurements of blanket assemblies at an accessible area to meet relevant criteria;
- comparison reports and records;
- verificaton of Material Balance Closing.



Rotating transfer lock: upper structure.

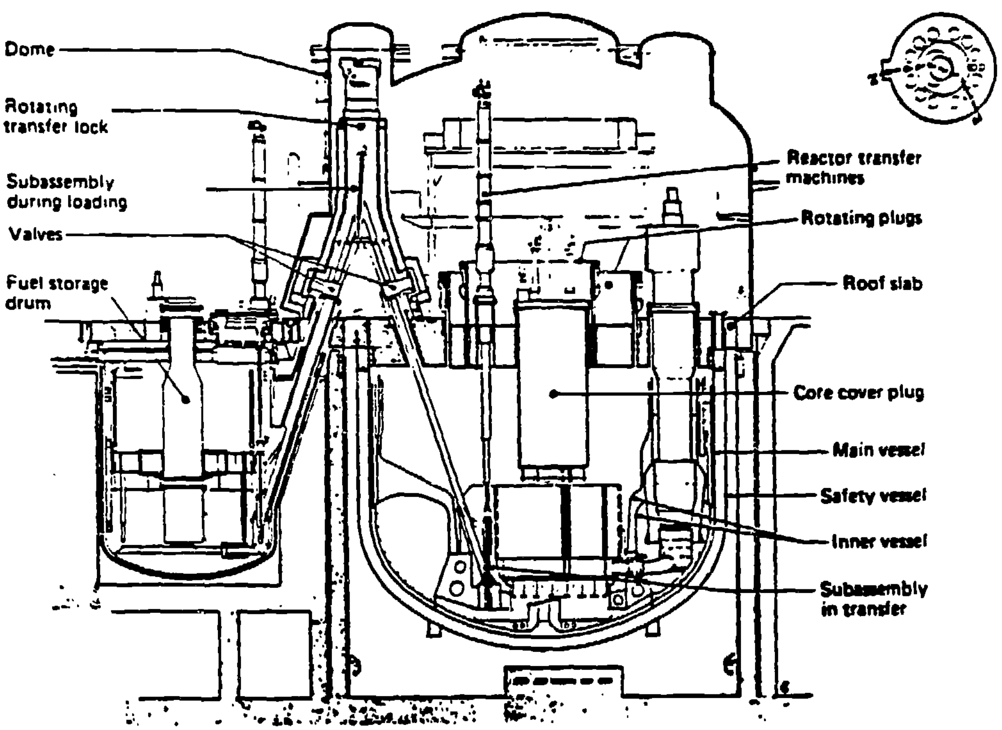
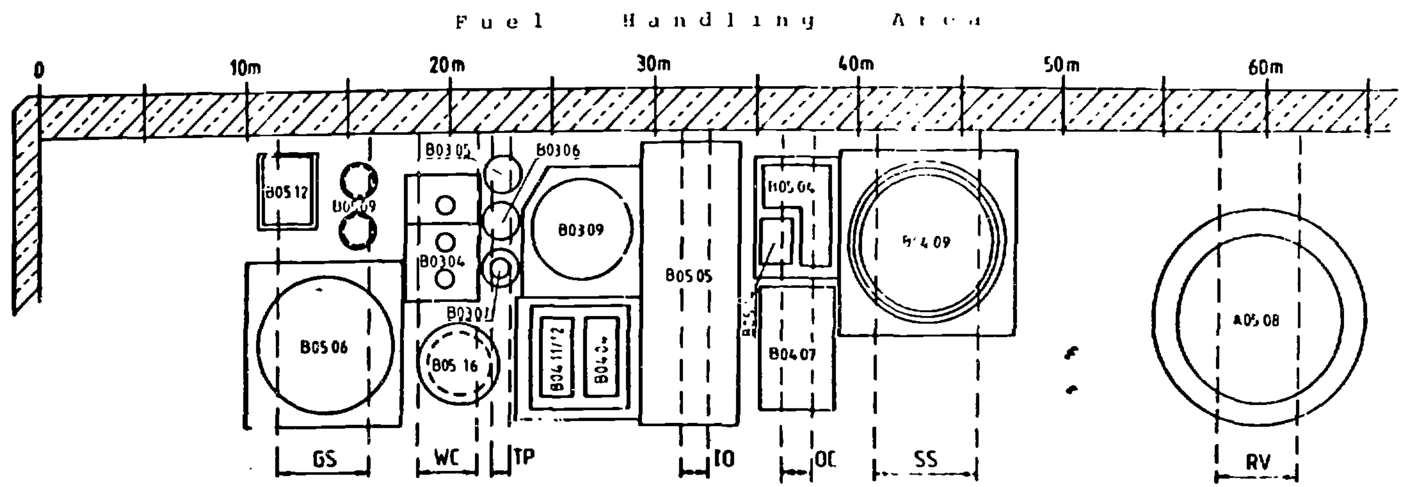


Fig. 1. Reactor block: cross section of the rotating transfer lock.

Handling area of the Kalkar power plant with the locations used for core assemblies

FIG. 2



Locations of the "Inaccessible" Inventory Area

GS	Gas Cooled Store	B05.06
WC	Washing Cell	B03.04
TP	Transfer Position	B03.07
IO	Shipping Cask Loading and Unloading Station	B05.05
OC	Irradiated Fuel Observation Cell	B04.07
SS	Sodium Cooled Store	B04.09
RV	Reactor Vessel	B05.08

Locations of the "Accessible" Inventory Area

New Fuel Store	B05.04
Auxiliary Station	B05.14
Shipping Cask Loading and Unloading Station	B05.05
Transfer Position	B03.07

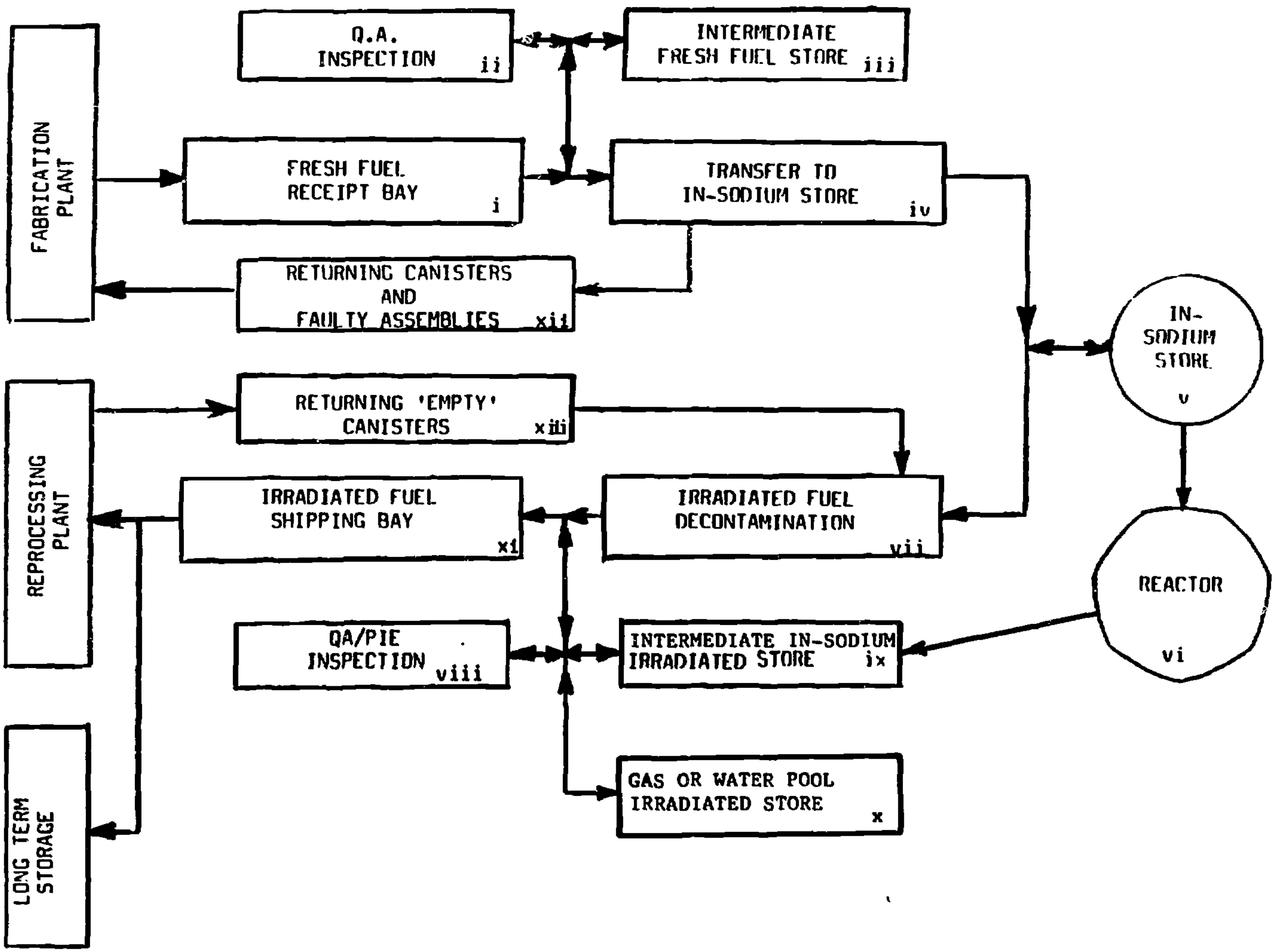


FIG. 3 SCHEMATIC OF FBR FUEL HANDLING ROUTE

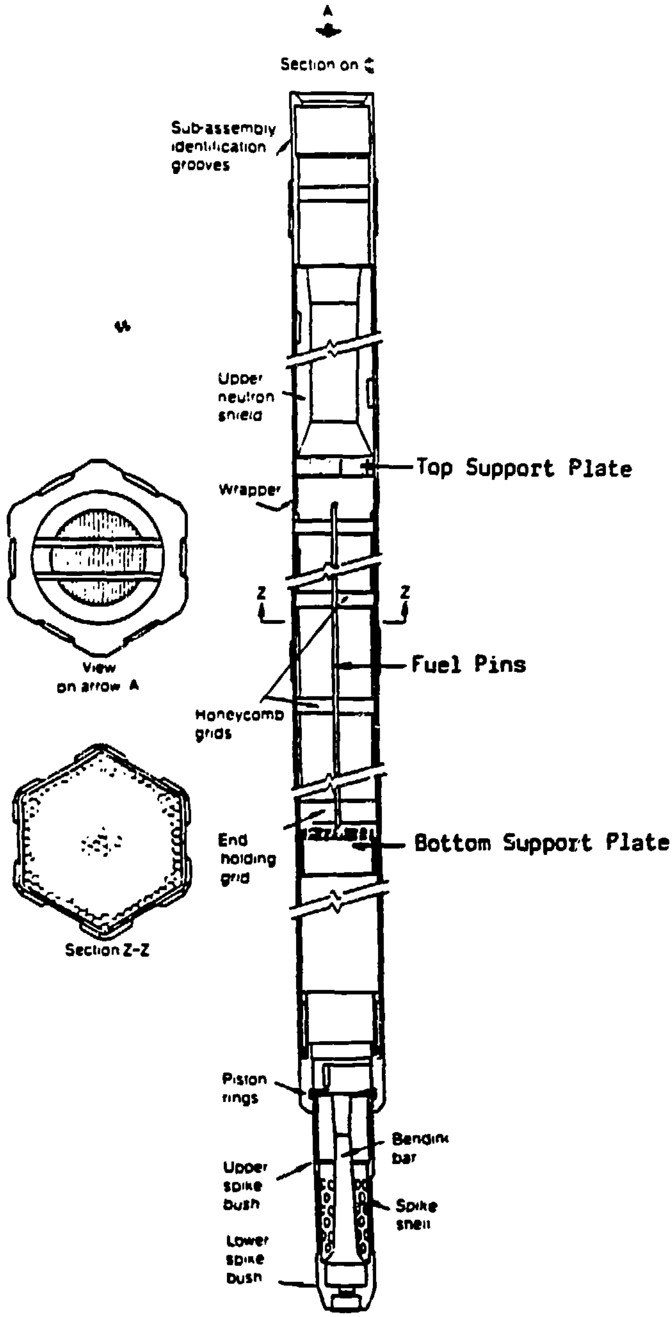


FIG. 4 THE REFERENCE DESIGN FBR SUB-ASSEMBLY